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**USAAVLABS TECHNICAL REPORT 66-43**

**UNITED STATES ARMY AVIATION  
CRASH SURVIVAL RESEARCH**

**SUMMARY REPORT**

**June 1966**

**U. S. ARMY AVIATION MATERIEL LABORATORIES  
FORT EUSTIS, VIRGINIA**

**CONTRACT DA 44-177-AMC-254(T)  
AVIATION SAFETY ENGINEERING AND RESEARCH  
A DIVISION OF  
FLIGHT SAFETY FOUNDATION, INC.  
PHOENIX, ARIZONA**

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**U. S. ARMY AVIATION MATERIEL LABORATORIES**  
**FORT EUSTIS, VIRGINIA 23604**

This summary report was prepared by Aviation Safety Engineering and Research (AvSER), a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-AMC-254(T). It provides a résumé of crash survival engineering and research projects pursued by this Command through contractual effort during the period October 1964 - September 1965.

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UNITED STATES ARMY AVIATION  
CRASH SURVIVAL RESEARCH

SUMMARY REPORT

1 October 1964 to 30 September 1965

AvSER 65-12

Prepared by

Aviation Safety Engineering and Research  
Phoenix, Arizona  
A Division of  
Flight Safety Foundation, Inc.

for

U. S. ARMY AVIATION MATERIEL LABORATORIES  
FORT EUSTIS, VIRGINIA

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## ABSTRACT

Analysis of U. S. Army aircraft accidents has revealed that accelerative loads on impact have been well within the limits of human tolerance in the majority of cases. Personnel involved in these accidents, however, have frequently suffered serious or fatal injuries as a result of the failure of some portion of the aircraft structure (e. g. , crushing of fuselage), failure of some major component (e. g. , crew seat), or postcrash fire.

Accordingly, the major emphasis in the projects conducted during the contract year was on improved structural crashworthiness, improved crash survival capability in seats and retention systems, and improved fuel containment in dynamic crash environments. The objective of the work effort in general was to develop more realistic crash survival design criteria for existing and future U. S. Army aircraft.

In addition to the areas cited above, effort continued in the areas of crash survival investigators' training, field investigation of pertinent aircraft accidents, and scientific liaison. All major work areas are reported in summary form.

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## AIRCRAFT ACCIDENT INVESTIGATIONS

Under this task, the Contractor was required to conduct crash injury investigations of selected military and civilian aircraft accidents which, in the judgment of the Contractor, have significant crash safety or crash survival aspects. Investigations were to give consideration to an evaluation of each accident to determine the basic airframe structural response, seat strength, adequacy of retention systems, postcrash fire phenomenon, causative injury factors, and other related statistical and engineering evaluation criteria.\*

On 10 July 1965, a U. S. Army CH-47 Chinook helicopter experienced a dual engine failure at a 400-foot altitude. The aircraft commenced an immediate autorotative glide. In the process of clearing some tall trees, rotor RPM was lost. Thus, insufficient rotor RPM existed to cushion the emergency landing. The aircraft settled in hard, which resulted in a vertical acceleration of 20-30G. The aircraft suffered strike damage, and the three crew occupants received serious injuries.

The crashworthiness investigation and evaluation indicated that the occupiable area volume reduction was small, that the engine and transmission attachments strengths were adequate, and that the crash safety aspects of the fuel tanks were most unsatisfactory. No fire resulted because neither engine was operating. Thus, most of the standard ignition sources were eliminated.

## CRASH SURVIVAL EVALUATION OF SELECTED AIRCRAFT AND/OR COMPONENTS

Under this task, the Contractor was required to review and comment on crash survival aspects of military and technical characteristics and model specifications for Army aircraft components or related equipment. The Contractor was also required to evaluate the crash survival aspects of current Army aircraft, mock-ups, and prepared designs as designated by the Contracting Officer.

An evaluation system that gives an indication of the relative crash survival potential of an aircraft has been developed as a result of accumulated experience in accident investigations and experimental crash tests. This system provides a numerical score for the aircraft in six major areas:

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\*This and all other requirements as set forth in the contract are paraphrased for the sake of brevity.



(1) crew retention, (2) passenger/troop retention, (3) postcrash fire potential, (4) basic airframe crashworthiness, (5) evacuation, and (6) injurious environment. These main areas are subdivided, and weighted values are assigned to each subfactor.

A crash survival evaluation was conducted on an OH-4A helicopter. The aircraft was then dynamically crash tested, and a comparative analysis was made of the precrash and postcrash evaluations. A comparison of the two different ratings indicates that a close correlation exists between the two evaluations. This close agreement appears to make the system worthy of use in the evaluation of preliminary aircraft and mock-ups of future Army aircraft.

A detailed description of the crash survival evaluation system and results of the OH-4A evaluation are covered in Memorandum Reports M65-5 and M65-9 as listed on page 24.

## CRASHWORTHINESS STUDY FOR PASSENGER SEAT DESIGN

The work performed under this task was conducted jointly by AvSER and the School of Engineering of Arizona State University. The study was sponsored by the Aviation Crash Injury Committee and funded jointly by the Army, Navy, Air Force, and NASA. This year's effort is Phase I of a 2-year study program. The study is scheduled for completion in October 1966. The study was divided into four broad areas. The following is a summary of the work performed in each of the areas.

### INVESTIGATION OF CRASH-INDUCED FLOOR ACCELERATIONS

Under this requirement, the Contractor was to conduct a theoretical and specialized test program to investigate crash cabin floor accelerations in order to:

1. Study and evaluate all available crash test data.
2. Analyze the influence of such factors as airframe structure (gross behavior analysis), ground conditions, impact velocity, accident configuration, and mass distribution upon the acceleration spectrum.
3. Correlate crash-test data with typical accident cases.
4. Develop a statistically significant range of crash pulse parameters in accident situations.
5. Develop an envelope of acceleration spectra for design purposes to apply an input to seat, equipment, and cargo retention systems.
6. Develop a specification of new test data needed, but not presently available, to place practical upper and lower limits on crash pulses and to define engineering design criteria.

Analyses of buckling loads were made for the DC-7 aircraft crash test; they showed that approximately 20G (longitudinal) is required to buckle the fuselage aft of the wing trailing edge even when only those longerons and stringers below the floor level are assumed to be active. For the full fuselage cross section, active values of at least 40-50G (longitudinal) could be realized on the rear portion of the occupiable volume. Similar analyses have been made by Convair for the 880 with comparable results.

In view of the fact that (1) these limiting G values are above the human tolerance range (seat belt only) and that (2) the effect of pulse duration and pulse shape on the seat-passenger response is not yet fully understood, this study was de-emphasized during this year's effort, while further developments in the "dynamic response" area were awaited.

## INVESTIGATION OF THE DYNAMIC RESPONSE OF SEAT-PASSENGER SYSTEMS TO TYPICAL CRASH PULSES

Under this requirement, the Contractor was to investigate the dynamic response of seat-passenger systems to typical crash pulses. This study effort will include, but will not be limited to:

1. A dynamic analysis employing postulated and mathematical models for the viscoelastic occupant, the elastic-plastic structure, and the input spectrum.
2. A study of the technical influence of simplifications on the comprehensive mathematical models.
3. Development of a computer program with sufficient generality to simulate nonlinear seat-occupant system behavior.
4. Experimental determination of load deformation characteristics of typical aircraft seats and components. The purpose of this investigation will be to develop an analytical technique which describes the required strength and plastic deformation properties of typical aircraft seats to establish optimum designs.

A mathematical model of a seat-passenger system using lumped parameters has been programmed for solution on the CDC 3400. The program is working, and six test runs have been made. The accuracy of the computer model is being evaluated and, when completed, will allow a complete analysis of the effect of the following variables on the response of seat-passenger systems to crash pulses:

1. Pulse shape
2. Pulse duration
3. Superimposition of pulses
4. Restraint system properties
5. Seat structural properties
6. Body mass and geometry
7. Muscle tension

The study will provide the following design information:

1. Head and leg impact velocities
2. Impact displacement of the body and its extremities
3. Seat loads and deflections
4. Restraint system loads

## **INVESTIGATION OF THE STRENGTH AND LOAD DEFORMATION CHARACTERISTICS OF AIRCRAFT SEATS**

Under this requirement, the Contractor was to investigate seat strength and load deformation characteristics through the following:

1. Analysis of the load deformation of typical Government and/or commercial aircraft seats under static loading and in supporting tests on seats and components.
2. Study of rate-of-loading effects, role of inertia forces in seat structure buckling strength, and rate effects on material properties and on connection resistances; comparative tests employing dynamic and static loading on similar structures.
3. Analysis of the ultimate strength of seat structure and connection configurations, with quasi-static loads and with impulsive loads; supporting tests to verify analysis; extraction of significant design features that control ultimate strength.
4. Analysis of energy-absorption characteristics of seat; definition of a seat's specific energy-absorption index that would have significance for its dynamic strength requirements; analysis of factors and design features that control this index, with supporting experimentation; analysis of local energy absorption at connections and the significance of this absorption under impulsive load applications.

Static and dynamic tests were conducted on seat structural components to obtain the following information: (1) load versus deformation data to be used as input for the computer load deformation study at Arizona State University and (2) comparison of energy-absorption characteristics under identical static and dynamic environments.

Jigs were designed to accomplish the tests. The jig design was complicated by the fact that maximum rigidity in the specimen's supporting structure was needed to insure accuracy of the deformation information between static and dynamic loadings. It was difficult to devise an accurate method of determining deformation versus load for the dynamic test. A photographic method and an electrical position indicator were used.

The results of the tests indicated that the ultimate load capacity of the specimens was the same for both static and dynamic environments. However, the energy absorbed was somewhat greater in the dynamic environment for the compression loadings on the seat legs. The rate of loading used in the tests was similar to the load rates which are experienced by aircraft seat legs in experimental aircraft crashes.

The load versus deformation data were plotted and incorporated in two computer programs in use in this study. The first accepts as inputs the body loading conditions and develops the requirements for seat deflection and energy-absorption requirements. The second accepts the component structural data and predicts the behavior patterns and failure points for the composite seat structure.

### SEAT AND SEAT RETENTION SYSTEM CONCEPTUAL DESIGN STUDY

Under this requirement, the Contractor was to conduct a conceptual study of improved seat and seat retention system design. This investigation included:

1. The establishment of overall requirements for a seat and retention system.
2. The development of such new principles and/or concepts in seating as are warranted by the overall requirements.
3. The integration of data into all design studies concerning (a) crash cabin floor accelerations, (b) dynamic response of seat-passenger systems to typical crash pulses, and (c) seat strength and load deformation characteristics. The data were to place emphasis on structural design principles useful to the manufacturer and provide inputs to a draft revised military standard for improved crew and passenger survival seats and body retention systems.
4. A proposal for specific design concepts to solve the head and leg injury problems experienced with present systems.

Methods of analyzing the head impact problem have been established, and typical impacts have been studied. The results indicate (based on the velocities obtained from the computer simulator) that large deflections must be achieved in the backs of seats to keep the head accelerations within tolerable limits.

Several configurations for the food tray in commercial seats have been evolved to assist in solving the head impact problem.

The effects of dynamic loading on stress concentrations have been investigated experimentally, and good results have been obtained. It has been clearly demonstrated that stress concentrations primarily affect the energy-absorption capability of the part and, in some cases, reduce the energy-absorption capacity by a factor of six to one.

## DYNAMIC CRASH TESTING OF AIRCRAFT, COMPONENTS, AND CRASH SAFETY EQUIPMENT

### OBJECTIVE

Under this task, the Contractor was required to conduct an experimental research program for the dynamic testing of aircraft, components, and crash safety equipment. In all crash tests, major experiments required under other clauses in the contract were to be included. The objective of the crash tests was to investigate crash dynamics phenomena to determine if crashworthiness in the basic structural design of aircraft and aircraft equipment could be improved through minor modifications.

### FULL-SCALE AIRCRAFT CRASH TESTS CONDUCTED

- T-16     C-45: Aircraft was guided by a rail/slipper system, accelerated by remote control, and impacted into a 30-degree earthen slope. Major experiments pertained to fuel containment, structural crashworthiness, and passenger protection.
  
- T-17     H-34: Aircraft was dropped to an asphalt runway by a moving crane. Major experiments pertained to fuel containment.
  
- T-18     H-21: Aircraft was dropped to an asphalt runway by a moving crane. Major experiments pertained to fuel containment and cargo restraint.
  
- T-19     C-45. Aircraft was guided by a rail/slipper system, accelerated by remote control, and impacted into a 30-degree earthen slope. Major experiments pertained to structural crashworthiness and fuel containment.
  
- T-20     YH-40: Aircraft was dropped to an asphalt runway by a moving crane. Major experiments pertained to litter retention systems.
  
- T-21     OH-4A: Aircraft was dropped to a hard dirt surface by a stationary crane. Major experiments pertained to crash survival evaluation and crew protection.
  
- T-22     OH-4A: Aircraft was flown and intentionally crashed by a remote control system. Major experiments pertained to crash survival evaluation and crew protection.

T-23     H-34: Aircraft was dropped to an asphalt runway by a moving crane. Major experiments pertained to fuel containment and cargo restraint.

T-24     C-45: Aircraft was guided by a rail/slipper system, accelerated by remote control, and impacted into a 30-degree earthen slope. Major experiments pertained to fuel containment and structural crashworthiness.

## RESEARCH PROGRAMS CONDUCTED IN CONNECTION WITH DYNAMIC CRASH TESTS

### PRINCIPLES FOR IMPROVING STRUCTURAL CRASHWORTHINESS IN STOL AND CTOL AIRCRAFT

The objective of the crash tests under this program was to investigate crash dynamics phenomena to determine if major gains in structural crashworthiness can be made through minor changes.

A summary of the crash tests conducted under this task is as follows:

TC-45J (T-16) - Test objectives were (1) to obtain base-line data for development of structural design criteria, (2) to investigate methods for improving fuel containment, and (3) to test an experimental inflatable "airbag" passenger seat.

To achieve objective (1), a C-45 fixed-wing aircraft was accelerated along a 2000-foot section of runway and impacted into an earthen mound having a 30-degree slope. The speed at impact was 84 knots. Both photo instrumentation and an electronic data recording system were aboard. This C-45 was not modified structurally. Impact acceleration data were collected on this unmodified aircraft to make comparisons with future crash tests with C-45 aircraft having structural modifications. The impact conditions in this test were severe, thereby causing large structural deformations, but living space remained in the occupiable area of the aircraft.

Objectives (2) and (3) are reported under other contractual requirements in this report.

TC-45J (T-19) - A C-45 aircraft with structural modifications in the nose section was accelerated along a 2000-foot section of runway and impacted into an earthen mound having a 30-degree slope. The previous C-45 crash test with unmodified structure showed that at moderate (30-degree) impact angles, where the impact occurs on the lower nose section, the structure collapses upward and inward. This changes the nose to an inverted scoop. The interaction between this scoop and the earth produces excessively high longitudinal forces, which, in turn, cause deformation of the cockpit structure and dangerously high longitudinal accelerations. The C-45 used in this test was structurally modified in the nose section to reduce cockpit deformation and high longitudinal acceleration. High-speed photographic coverage and post-crash wreckage analysis indicated that, with minor structural changes



in the nose section, a significant increase in crashworthiness can be achieved.

TC-45J (T-24) - The third C-45 aircraft in this test series was prepared and crash tested in the same manner as the two previous aircraft. The second test (T-19) indicated that minor nose modifications could significantly increase the overall crashworthiness of the aircraft by reducing longitudinal accelerations and cockpit deformation. Despite such improvements, however, it was found that considerable structural deformation occurred in the aft section of the passenger cabin. This was caused by the combination of longitudinal loading and a bending moment produced by the "pitch-up" nose rotation, so that living space in the cabin was thereby reduced. For this test, the upper aft passenger cabin was strengthened to prevent buckling and to improve survivability. The nose was modified as in the previous (T-19) test.

The forward speed of the aircraft just before impact was slightly less than that in the two previous tests, owing, no doubt, to inferior engine performance. Because of the lower speed, initial impact occurred not at the nose as before but at the lower engine nacelles. This caused the aircraft to pitch up and thereby negated the influence of the nose modification. It was apparent, however, that the aft fuselage modification had the desired effect, since a higher degree of living space was maintained than in previous tests.

#### POSTCRASH FIRE RESEARCH

Under this task, the Contractor was required to study the hazards associated with aircraft crash and postcrash fire, including existing fuel tank installations in Army aircraft, and to conduct an evaluation thereof under dynamic crash test conditions. The Contractor was also required to investigate new methods and techniques for fuel containment, including the use of fiber glass tank liners, improved bladder cell designs, honeycomb tank fillers and liners, and fuel solidification.

The fuel tank crash containment problem was broken down into three major areas: large fuel cell installations (H-21 and H-25 type); under-floor fuel cell installations (H-34 type); and wing cell installation (TC-45 type).

Initially, a study was conducted to determine the behavior of various internal fuel cells while they were undergoing crash impact accelerations. Of particular interest was the behavior of the structural environment surrounding the fuel cells.

Once the fuel cell and structural environment during crash impact accelerations was defined, it was possible to proceed with the task of developing experimental fuel cells. Several fuel cell manufacturers assisted in this development. Fuel cells of various configurations and materials were constructed. They consisted of various combinations of nylon laminates, nylon, felt, metal, rubberized cloth, and other materials. Several experiments were conducted in which these specially constructed fuel cells were installed in both rotary- and fixed-wing aircraft and then the aircraft were subjected to crash impact environments. Varying degrees of success were achieved with the different types of cells. Some failures were incurred. Some cells performed exceptionally well under particularly severe impact conditions. It is believed that during the research conducted under this task, much progress was made toward the achievement of optimum fuel containment during potentially survivable aircraft accidents.

#### DYNAMIC CRASH TEST OF TWO OH-4A LIGHT-OBSERVATION-TYPE HELICOPTERS

Under this task, the Contractor was required to conduct dynamic crash tests with two OH-4A LOH-type helicopters. The first test was to consist of a static drop from a height that would result in an impact velocity of 25 feet per second. The second aircraft was to be crashed by remote-controlled flight at a forward speed of 25 knots, at a vertical speed of 25 feet per second, and at a level attitude, onto even, moderately packed soil. The specific areas of interest to be investigated were as follows:

1. Postcrash fire protection
2. Protective qualities of existing floor construction
3. Dynamic strength of crew seats
4. Adequacy of restraint systems and inertia reels
5. Personnel injury potential (by means of crash survival evaluation techniques and high-speed photography)
6. Injury potential of transmission or engine mount failure on impact
7. Roll-over protection qualities
8. Postcrash ingress and egress provisions

Two experimental crash tests of fully instrumented OH-4A LOH-type helicopters were conducted. The first of these tests, conducted as a crane drop, illustrated the energy-absorption capability of the tapered-wall landing gear strut. It further showed that high accelerations may be induced in occupants under flat impact attitude conditions in which the design sinking speed for the gear is exceeded. The latter of these tests, conducted from droned flight, indicated that rotor blade impacts

with obstacles induced loads into the mast-transmission system which were sufficient to fail the structure at the transmission supports.

The crashworthiness of the OH-4A showed an improvement over previous aircraft tested; however, further improvements are definitely possible. The final report on this work recommends how such improvements can be made and proposes their implementation through appropriate study and test programs.

#### MEDICAL EVACUATION EQUIPMENT STUDY

Under this task, the Contractor was required to conduct a study of medical evacuation equipment and other related crash survival furnishings and equipment. A drop test and a full-scale test of prototype litters were to be conducted in the YH-40 helicopter crash test. Analysis of results and recommendations were required.

Strength requirements of U. S. Army litter/patient retention systems as set forth in current military specifications were analyzed. The analysis was made in light of U. S. Army aircraft accident experience, the human tolerance to abrupt accelerations, and the forces and accelerations that may be anticipated in accidents involving litter-bearing military aircraft. The analysis revealed that the strength requirements quoted in current military specifications are considerably lower than (1) the upper limits of acceleration that can be tolerated by airborne litter occupants and (2) the typical forces and accelerations that are incurred in military aircraft accidents.

These conclusions indicated that current litter systems would fail under relatively moderate impact conditions and would thus subject the litter patient to amplified accelerations and increased contact injuries.

An experimental litter system, incorporating criteria believed to be valid, was developed and tested in a dynamic crash test environment. On the basis of past research and of the analysis of test data derived during this study, it was recommended that U. S. Army aeromedical litter systems specifications be modified to reflect the following strength requirements: 20G in the vertical direction while stroking through at least 12 inches of travel;  $25G \pm 5G$  in axes parallel to the plane of the litter.

#### HELICOPTER CARGO TIE-DOWN CRASH TEST

Under this task, the Contractor was required to conduct a cargo restraint experiment in an H-21A helicopter in a dynamic crash impact environment. The objective of the experiment was to determine the

effectiveness, under high vertical impact acceleration conditions, of a cargo restraint system designed to prevent cargo shifting under in-flight loads.

Two 500-pound simulated cargo loads were installed in the test vehicle. Two methods of restraint were provided. Nylon straps were used to secure one load to 4.0G (-Ax), 2.0G (+Ax), 2.0G (+Az), and 1.5G ( $\pm$ Ay). The second load was restrained in the -Ax axis by load limiters designed to limit it to 4.0G. Standard restraint were used in the z and y axes. The test vehicle was dropped from 30 feet at a forward speed of 30 miles per hour. Vertical and horizontal velocities were approximately 41 feet per second. Peak accelerations at the floor were 88G (+Az), 52G (-Ax), and 25G ( $\pm$ Ay). Upon impact, the load restrained by nylon straps broke loose, whereas the load-limited cargo remained in place.

#### UH-1 CHEST PROTECTOR DEVICE

Under this task, the Contractor was required to subject a chest protector armor system for the UH-1B aircraft configuration to a dynamic crash impact environment. A CH-21A was to be used for a test vehicle, and a YH-40 crew seat (modified to simulate a UH-1B seat) was to be used for attachment of the armor system.

The armor system tested consisted of a UH-1B pilot seat armor kit and a copilot chest protector kit. These two kits were installed on a modified YH-40 seat. The test objective was to determine whether this crew armor would produce injury in a moderately severe crash impact and, if so, to determine ways to reduce its injury potential. When the test was conducted, the vertical impact velocity of the CH-21A was 42 feet per second and the horizontal velocity was 41 feet per second. All components of the armor kit remained attached to the seat on impact, and the seat remained in place. The increased vertical loading caused the seat height mechanism to fail, and the seat moved downward against the lower support mechanism. The chest protector armor plate support bar was bent forward during the impact, and two of the four brass screws which attached the armor material to the support arm failed. This failure allowed the armor material to hit the upper thigh of the dummy, leaving a small indentation in the honeycomb leg. This indentation was not considered to be significant enough to be classified as a potential injury to a human occupant.

#### DYNAMIC TEST OF CARGO RESTRAINT SYSTEMS

Under this task, the Contractor was required to conduct dynamic tests of two cargo restraint systems. The loads in each test, to be conducted

concurrently, were to be restrained for 4.0G (+Ax), 2G (-Ax), 1.5G ( $\pm$ Ay), and 1.5G (+Az), respectively. One of the tests was to be conducted without load limiters in the restraint system, and the other test was to incorporate load limiters with a cumulative yield value of four times the load weight (500 pounds) for restraint against forward motion. The objective was to determine the effectiveness of cargo restraint designed to withstand flight loads only but to use an energy-absorbing attachment to allow limited forward movement of a wheeled cargo load under actual crash conditions.

Each of the two loads consisted of a wheeled cart weighing 500 pounds. Instrumentation was provided to measure aircraft floor accelerations, cargo load accelerations, and load-limiting force level on the aft vehicle. High-speed photographic coverage was also provided.

The test vehicle (H-34) was dropped from a moving crane onto an asphalt taxiway. Vertical sink speed and horizontal speed on impact were approximately 40 feet per second. Cargo cabin floor accelerations were 130G vertically, 49G longitudinally, and 20G laterally. The forward vehicle (not load limited) broke free from its restraint and impacted into the forward cabin bulkhead. The aft vehicle, incorporating load limiters, was adequately restrained and remained in the center of the floor. These results were similar to a previous experiment in which one palletized cargo load was limited with simple energy absorbers and the other was not. These tests indicated the effectiveness of simple energy-absorbing devices to restrain cargo under certain types of crash loading.

#### AIRCRAFT SEAT AND SEAT COMPONENT TESTING

Under this task, the Contractor was required to conduct a seat and seat component test program to include the following:

1. Six dynamic tests of seat legs
2. Two full-scale seat tests (one static and one dynamic)

The purposes of these tests were to verify computer program predictions and to improve existing math models of full-scale seats and seat components previously developed.

Tubular steel and sheet metal seat legs were removed from standard double-passenger airline seats. These seat legs were loaded dynamically by the use of an appropriate drop jig in a drop tower. The rate of loading was controlled upon impact by the use of paper honeycomb of varying cross-sectional area underneath the drop jig. The load

represented a forward load for the entire leg assembly. The following tests were completed:

Tension on sheet metal, aft seat leg - 2 tests  
Compression on sheet metal, forward seat leg - 2 tests  
Torsion on steel tube, forward seat leg - 2 tests

Two double-passenger airline seats with tubular steel construction were obtained for static and dynamic tests. The load was applied until failure occurred in both the static and the dynamic tests. The load was applied longitudinally at a 28-degree downward angle to simulate a downward component equal to nearly half of the forward component. The primary failure in the seat occurred in the lap belt attachment fittings at a resultant load of about 16G (in the static test).

Although a prior failure did occur in the seat pan, this failure would not have caused a loss of the seated passenger, but it would have permitted "submarining" of the torso.

The data from the static and dynamic tests were analyzed, and a comparison was made between the kinematics of the anthropomorphic dummy (taken from high-speed motion picture photography) and the simulated body kinematics derived from a computer study.

#### DYNAMIC CRASH TEST OF AN EXPERIMENTAL INFLATABLE AIR SEAT

Under this task, the Contractor was required to subject an experimental air-inflated passenger seat to a dynamic aircraft crash environment. An anthropomorphic dummy, restrained by a seat belt only, was to be installed in the seat, which was oriented in the aft-facing position. The objective was to determine if this seat, developed for NASA, offered increased occupant protection in a dynamic crash environment.

The air seat and dummy were installed in a TC-45J fixed-wing aircraft. Instrumentation was provided to record acceleration and air seat pressure data. The aircraft was accelerated down a 2000-foot section of prepared runway and was guided by slippers attached to a single railroad rail. The aircraft impacted into a 30-degree earthen mound at 108 miles per hour. On impact, the seat back bent forward (toward the front of the aircraft). The lap-belt cam-type buckle allowed the belt to slip, and the dummy occupant came out of the seat. Peak accelerations measured on the dummy reached 76G longitudinally and 64G vertically.

**DRAFT MILITARY STANDARD FOR IMPROVED CREW AND  
PASSENGER SURVIVAL SEATS AND BODY RETENTION SYSTEMS**

Under this task, the Contractor was required to investigate and develop a draft revised military standard for improved crew and passenger survival seats and body retention systems.

The engineering criteria and principles used to develop the military standard were derived primarily from past AvSER crash survival projects pertaining to occupant retention research. Criteria were based upon the human tolerance to impact acceleration and crash impact accelerations known to occur in aircraft accidents of a severe but survivable nature.

## AIRCREWMAN PROTECTIVE HEADGEAR

Under this task, the Contractor was required to analyze data covering all aspects of the previous year's effort on head protective devices and techniques. This analysis was to be devoted to a correlation study of existing test data on energy-absorption and head-deceleration phenomena and existing theories to determine the validity of employing empirical design techniques. The Contractor was also required to develop test criteria and techniques and to conduct a structural analysis of a shell-liner and energy-absorption-material combination.

The following work under this requirement was accomplished:

1. The existing APH-5 type helmet retention harness was tested by installing the harness on anthropomorphic dummies and subjecting them to decelerative force of from 20 to 40G (-Ax). These tests indicated that the chin strap strength is inadequate to retain the helmet on the head in such an environment. The snap fastener on the chin strap failed in two cases.
2. Helmet retention tests were also conducted with a cadaver at Wayne State University. These tests did not result in any failures of the retention harness; however, the tests did reveal that excessive stretch occurs in a nylon net retention harness and that this stretch permits the helmet to rebound backward after the initial impact to such an extent that little protection is offered to the forward region of the head.
3. Impact tests were conducted on simulated helmet specimens to determine the difference in the acceleration pulses recorded. Tests were conducted by two methods: (a) head-form drop method - accelerometer mounted inside a metal head form with the entire assembly dropped onto an impact surface and (b) impact mass drop method - accelerometer mounted inside a rigid drop mass equal in weight to the head form with the drop mass impacting against the simulated helmet. The impact tests indicated little recorded difference in the acceleration pulses between the two drop methods for identical conditions. The head-form drop method did result in more high-frequency oscillations in the acceleration traces than did the drop mass method; however, this phenomenon can probably be eliminated by redesign of the head-form and drop-cage mechanism. It can be concluded that the drop mass method of impact testing is satisfactory and that it is the most simple test method to use.



## CRASH INJURY INVESTIGATORS' TRAINING

Under this task, the Contractor was required to conduct 3 training courses, each of 2 weeks' duration, in crash injury investigation for the purpose of training 40 military students to be designated by the Government.

During the 3 classes scheduled for fiscal year 1965, 39 U. S. Army personnel were trained. Among this group, there were 14 aviation medical officers, 3 Medical Corps officers, and 22 Army officers with other specialties. A last-minute cancellation in the last class by 1 officer prevented the training of 40 officers as required by contract. In addition to the U. S. Army officers trained, there were 7 civilians, 3 Air Force personnel, and 1 Public Health Service flight surgeon who represented the U. S. Coast Guard. In all, 50 students were trained during the school year. Eleven of these were in excess of those trained under the terms of the contract. The general reaction to the instruction offered as determined by critique sheets was excellent.

## SCIENTIFIC LIAISON

Under this task, the Contractor was required to maintain liaison with groups and agencies concerned with aviation crash survival research. The Contractor, subject to the approval of the Contracting Officer, was to furnish engineering and management personnel to participate in conferences, meetings, forums, symposia, and seminars related to the objectives of the contract program.

### CONFERENCE ATTENDED - NASA CONFERENCE ON AIRCRAFT OPERATING PROBLEMS, LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA

Mr. V. E. Rothe attended this conference from 10-12 May 1965. Some of the pertinent subjects discussed relating to aviation safety were as follows:

- Traction of Pneumatic Tires on Wet Runways
- Some Factors Affecting Fatigue of Aircraft Structures
- Operational Experiences of General Aviation Aircraft
- Operating Problems Peculiar to V/STOL Aircraft

The contacts made and the discussions held with aviation safety authorities were considered to be an important liaison activity under the terms of this contractual requirement.

### CONFERENCE ATTENDED - 36th ANNUAL SCIENTIFIC MEETING OF THE AEROSPACE MEDICAL ASSOCIATION, NEW YORK, NEW YORK

Messrs. V. E. Rothe and L. L. Milhone attended this conference from 26-29 April 1965. Major W. H. Hawkins, the Army Liaison Officer with AvSER, attended under the auspices of the Surgeon General's Office. A joint U. S. Army/Flight Safety Foundation exhibit was set up in the display area and manned continuously. An encouragingly high number of attendees visited the exhibit and requested information on the U. S. Army Crash Survival Investigators' School, experimental crash test activities, postcrash fire research, and head protective device research. Many interesting and highly informative presentations directly applicable to the U. S. Army's Crash Survival Research Program were given. This conference is considered to be one of the most important liaison activities under the terms of this contractual requirement.

CONFERENCE ATTENDED - AVIATION CONTRACTORS' SAFETY  
REPRESENTATIVES' CONFERENCE, NAVAL AVIATION SAFETY  
CENTER, NORFOLK, VIRGINIA

This conference was attended by Mr. H. G. C. Henneberger from 4-9 April 1965. Its purpose was to provide recommendations for problems affecting Naval aviation safety. Committees were arranged to permit members to exchange information and to discuss possible solutions to the problems. Committees were on Human Factors, Maintenance, Operations, and Personal Safety and Survival Equipment. Mr. Henneberger was a member of the committee on Personal Safety and Survival Equipment. Some of the subjects discussed in this committee were: emergency in-flight escape at low altitude/airspeed; methods of information exchange between military and civilian activities; problems affecting parachute canopy deflation; life vest dye marker for search and rescue purposes; pilot emergency locator devices; survival kits; oxygen systems; and droppable search and rescue kits. During the conference, valuable discussions were held with U. S. Navy and Coast Guard personnel regarding the U. S. Army's Crash Survival Research Program. Prior to Mr. Henneberger's attending the conference, similar discussions were held with interested BUWEPS personnel. It is believed that it is in the interest of the U. S. Army to have continued AvSER representation at this annual conference.

CONFERENCE ATTENDED - EIGHTH STAPP CAR CONFERENCE,  
WAYNE STATE UNIVERSITY, DETROIT, MICHIGAN

This conference was attended by Mr. J. L. Haley from 21-23 October 1965. Some of the pertinent presentations given were:

- Automotive Crash Injury Review
- Injury in Nonfatal Accidents
- Human Tolerance to Lateral Impact with Lap Belt Only
- Clinical Application of Experimental Injuries
- Head Motions During Impact
- Survey of Human Simulation Techniques
- Comparison of Standard and Experimental Windshields
- Correlation of Experimental and Real Accidents
- Case Studies of Racing Accidents
- Three-Point Belt and Shoulder Restraint
- Sled Tests of Seat Belts
- Dynamic Tests of Restraint for Children

In addition to papers given, the following other activities were conducted:

- Tour of Ford Motor Proving Ground
- Tour of General Motors Proving Ground
- Tour of Wayne State Biomechanics Laboratories
- Tour of Helmet Manufacturing Company (Buegeleisen)

The subjects discussed and the contacts made at the annual Stapp Car Conference are considered to have direct applicability to the U. S. Army's Crash Survival Research Program. This conference is particularly recommended for future attendance.

ACTIVITY ATTENDED - MEETING AT U. S. ARMY AVIATION  
MATERIEL COMMAND (USAAVCOM), ST. LOUIS, MISSOURI

In response to a request by the Contracting Officer, U. S. Army Aviation Materiel Laboratories (USAAVLABS), Mr. V. E. Rothe made a presentation to USAAVCOM personnel on the U. S. Army's Crash Survival Research Program conducted at AvSER. A 3-hour presentation, covering the most significant aspects of the program during the past 5 years, was made.

CONFERENCE ATTENDED - NATIONAL RESEARCH COUNCIL

This conference, on the subject of head protective device research, was attended by Mr. J. L. Haley from 23-24 June 1965. The agenda for the conference consisted of presentations on the following topics:

- Mechanics and Threshold of Head Damage as a Result of Impact
- New Concepts in Transducers and Intercommunication Systems for Helmets
- New Principles and Techniques for Reducing Noise at the Ears
- New Techniques and Principles in Helmet Design
- Principles of Helmet Design To Increase Impact Protection
- Development of Heat Regulating Systems for Headgear
- Establishment of the Force and Point of Impact to Which the Head Is Subjected During Aircraft Crashes

Mr. Haley made the presentation on the last subject listed. Although the expenses for attending this conference were borne by the National Research Council, it is considered to be significant to this contractual requirement and is listed herein accordingly.

CONFERENCE ATTENDED - NATIONAL AVIATION FACILITIES  
EXPERIMENTAL CENTER (NAFEC) CONFERENCE ON AIRCRAFT  
SEAT TESTING

At the request of the USAAVLABS Contracting Officer's Technical Representative, this conference was attended by Mr. J. L. Haley from 15-18 March 1965. There were approximately eight participants at the conference who represented FAA, USN, USAF, and USA. Each participant was requested to discuss the seat testing and development work being conducted at his respective facility. In addition to discussing seat testing and development work for the U. S. Army, Mr. Haley recommended that the agencies represented review the results of USAAVLABS work on seating and consider the use of the resulting criteria in their own specifications for new seats.

TECHNICAL REPORTS PERTINENT TO  
CONTRACT DA 44-177-AMC-254(T)

Turnbow, J. W., et al, Full-Scale Dynamic Crash Test of a Small Observation Type Helicopter, USAAVLABS Technical Report 66-32, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, May 1966.

Weinberg, L. W. T., Aircraft Litter Retention System Design Criteria, USAAVLABS Technical Report 66-27, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, April 1966, AD 632457.

Robertson, S. H., Turnbow, J. W., Aircraft Fuel Tank Design Criteria, USAAVLABS Technical Report 66-24, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, March 1966, AD 631610.

Haley, J. L., Jr., Turnbow, J. W., Impact Test Methods and Retention Harness Criteria for U. S. Army Aircrewman Protective Headgear, USAAVLABS Technical Report 66-29, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, March 1966, AD 631493.

Robertson, S. H., U. S. Army CH-47 Chinook Helicopter Accident, Fort Benning, Georgia, 10 July 1965, USAAVLABS Technical Report 66-38, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, May 1966.

Reed, W. H., Avery, J. P., Principles for Improving Structural Crashworthiness for STOL and CTOL Aircraft, USAAVLABS Technical Report 66-39, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, June 1966.

MEMORANDUM REPORTS PERTINENT TO  
CONTRACT DA 44-177-AMC-254(T)

<u>REPORT NO.</u>	<u>TITLE</u>
M65-1	Cargo Restraint Experiment T-18, CH-21 Crash Test
M65-3	Dynamic Crash Test of Two UH-1D Helicopter Crew Seats
M65-4	Dynamic Test of a Rear Facing Air Seat
M65-5	Crash Survival Evaluation of the OH-4A Helicopter
M65-6	Reduction in Postcrash Fire Through Improved Fuel Containment
M65-7	Full-Scale Dynamic Test of a Small Observation Type Helicopter, Test 21
M65-8	Full-Scale Dynamic Test of a Small Observation Type Helicopter, Test 22
M65-9	Crash Survival Evaluation - OH-4A Helicopter
None Assigned	UH-1 Chest Protector Support Test
AvSER 65-14	Proposed Military Standard for Improved Crew/ Passenger Survival Seats and Body Retention Systems
AvSER 65-20	Crashworthiness Study for Passenger Seats and Restraint Systems - Phase I

## TECHNICAL FILM REPORTS

### HELMET DESIGN CRITERIA (12 minutes)

A discussion of problems associated with existing U. S. Army Aviator helmets and theoretical design criteria for a new helmet is presented. In existing helmets, crash protection is compromised by inadequate design. Some theoretical concepts for achieving increased protection with no weight penalties are given.

### EXPERIMENTAL CREW SEAT DESIGN AND TESTING (15 minutes)

A discussion of various energy attenuating devices incorporated in four experimental crew seats and restraint systems is presented. Each seat system was designed in accordance with criteria established during several years of full-scale crash tests. Seats were exposed to abrupt accelerations in different orientations. Of interest is a discussion of the dynamic overshoot phenomena where accelerations in excess of input are experienced on dummy occupants of the seats and the seat systems.

### SEARCH FOR ADEQUATE BIOLOGICAL INDICATORS (13 minutes)

This film points out the need for crash survival research to develop adequate correlation factors between live animal experimentation and man and to determine biological indicators. Dynamic responses of animals and accelerations during testing are compared with the same factors experienced with anthropomorphic dummies in the same test environment.



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13 ABSTRACT Analysis of U. S. Army aircraft accidents has revealed that accelerative loads on impact have been well within the limits of human tolerance in the majority of cases. Personnel involved in these accidents, however, have frequently suffered serious or fatal injuries as a result of the failure of some portion of the aircraft structure (e.g., crushing of fuselage), failure of some major component (e.g., crew seat), or postcrash fire. Accordingly, the major emphasis in the projects conducted during the contract year was on improved structural crashworthiness, improved crash survival capability in seats and retention systems, and improved fuel containment in dynamic crash environments. The objective of the work effort in general was to develop more realistic crash survival design criteria for existing and future U. S. Army aircraft. In addition to the areas cited above, effort continued in the areas of crash survival investigators' training, field investigation of pertinent aircraft accidents, and scientific liaison. All major work areas are reported in summary form.		

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Enclosure 1

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